

# Economic Impact of Cloud Computing in the Health System: A Systematic Mapping

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**Abstract-** Cloud computing has become one of the most widely used technologies today, bringing positive impacts to its adopters and changing the way many areas work, impacting their solutions in the market. The healthcare system can enjoy the same benefits brought by the adoption of this technology, improving its infrastructure, reducing its costs tremendously and speeding up processes. With that in mind, what are the economic impacts of adopting cloud computing on healthcare environments? This paper conducts a systematic mapping in order to depict the economic and other impacts of cloud computing in the healthcare system and solutions, analyzing aspects that go beyond the technological issues.

**Keywords -** Cloud computing; economic impacts; health; challenges.

## I. INTRODUCTION

Cloud computing is one of the most impactful technologies of recent times. Not surprisingly, large companies are embracing this infrastructure paradigm with significant economic gains. Highly discussed technologies such as blockchain, conversational platforms, and artificial intelligence have in common the use or need for cloud computing [1].

According to the National Institute of Standards and Technology (NIST), Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. Comparing with the traditional Information Technology (IT) model, cloud computing presents a fundamental change in the way IT services are developed, deployed, maintained and paid for.

As global population increases, life expectancy rises, and living standards improve, causes of death across the world are changing [2]. Heart disease and cancer are the leading causes of death. The health system, like any other, needs continuous and systematic innovation to deliver high quality, safe and cost-effective services. A well-adopted

cloud gives a lot of advantages to the organization such as easy and pervasive access to data and applications, increases cost-effectiveness [3].

The purpose of this article is to study the economic impacts of the use of cloud computing in the health area. This work is organized as follows: first, in Section 2, basic concepts related to cloud computing and the methodology used will be presented together with the objectives of the study. Then, in Section 3 the methods, processes, and protocols applied in the elaboration of systematic mapping will be described. Finally, in Section 4, we will present the results obtained, conclusions and plans for future work.

## II. APPLIED PROTOCOL

Based on the guidelines for developing systematic software engineering reviews in software engineering described by Kitchenham [4], a new methodology for revision was created. The purpose of this review is to identify primary studies that focus on the use and benefits of cloud computing adoption based on the following question:

- *What is the economic impact on cloud computing adoption in health/healthcare environments?*

This main question intends to focus not only on the technological impacts of using cloud computing, but also to conduct research on related, but not limited, topics such as economics, time-saving, improved treatment, and other non-technological factors. However, it is expected that, during the analysis features, such as security, privacy, complexity, and others, appear as factors that may limit the adoption and use of cloud computing.

From this central question, secondary questions were created to help in understanding and comprehension of the problem:

1. What areas of health can benefit from using Cloud Computing?

2. What is the economic impact of Cloud Computing on disease control and treatment?
3. What are the main challenges and opportunities for using cloud computing in health environments?

*A. Inclusion and Exclusion Criteria*

For this review, we considered studies that depict information and data related to cloud computing adoption, usage, positive and negative impacts. This review limited the examined studies to the ones published starting from year 2015.

Were also excluded:

- Studies whose focus was only on technical aspects;
- Studies not published in the English language;
- Studies that were unavailable online;
- Studies not based on research and that are not full papers;
- Call for works, prefaces, conference annals, handouts, summaries, panels, interviews, and news reports.

*B. Search Strategies*

The databases considered in the study is on the list below:

- ACM Digital Library;
- IEEE Xplore;
- Science Direct;

Combinations of terms were created to guarantee that relevant information would not be excluded when querying different search engines and databases. As a result, four search strings were created:

1. (Cloud Computing) AND (Economic OR Economy OR Business OR Benefits) AND (Health);
2. (Cloud Computing) AND (Adoption OR Migration) AND (Health);
3. (Cloud Computing) AND (Challenges OR Opportunities) AND (Health);

In the process of extracting information from the databases, the search strings were used separately on each database. The searches were performed restricting the years between 2015 and 2019. The results of each search were grouped together according to the database and were, later, examined closer in order to identify duplicity.

*C. Studies Selection Process*

This section describes the selection process from the beginning: from an initial search using the Search Strategies described below to the identification of primary studies. In the first step, the studies that were obtained from the databases were gathered and added to a management citation tool, the authors’ choose Mendeley. Next, once the initial studies were selected, the titles of all works selected were analyzed to determine its relevance in this systematic review. In this stage, an initial filter is conducted removing works that did not present relevant topics for this research. When the works’ titles were vague or unclear, they were put aside to be analyzed in the next step. Since the main intention was to analyze aspects not specifically related to technology, works that mentioned security or big data, and others, were selected for further analysis during the abstract reading. At the end of this stage, 5138 citations were excluded, thus remaining 142 items for further analysis.

In the third step, all abstracts of the Works found in the previous one were assessed. Once more, many were eliminated from the study due to them not conforming to the scope of cloud computing and topics not related only to technologies. One of the difficulties found in this step was related to the quality of the abstract, a portion of the abstract was not clear about the main topic addressed by the work. When that happened, the authors did a deeper analysis reading introduction and conclusion looking for topics and sentences related to this research. Because of this phase, 103 studies were excluded, thus remaining 39 to be analyzed more closely. Table 1 presents the amount of studies filtered in each step of the selection process.

TABLE I. AMOUNT OF STUDIES FILTERED IN THE SELECTION PROCESS

	ACM Digital Library	IEEE Explore	Science Direct	Total
Initial	593	1656	3031	5280
Title	39	65	38	142
Abstract	8	20	11	39

For qualitative and quantitative assessment, seven questions were used to assist in quality assessment. The questions are:

1. Does the study examine impacts and/or economic aspects related to cloud computing adoption in healthy environments?
2. Does the study present aspects related to solutions that use cloud computing?

3. Does the study present aspects related to challenges or opportunities in health?
4. Is the study based on research - not merely on specialist's opinions?
5. Is the context of the study adequately described?
6. Were the research results adequately explained and described?
7. Does the study contribute to the research of cloud and health in any way?

The research process that was developed resulted in 39 primary studies. They were written by 119 institution-related authors and were published between 2015 and 2019. As described in the previous Section, each of the primary studies was evaluated according to 7 quality criteria regarding the rigor and credibility of the research in addition to relevance to the topic addressed. Brought together, these 7 criteria provide a measure of reliability for the conclusions that a particular study can bring to the review. The classification for each of the criteria used a scale of positives (1) and negatives (0) and is presented in Table 2.

TABLE II. EXTRACTION OF QUALITY ANALYSIS OF PRIMARY STUDIES STUDY

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Total
{5}	1	1	1	1	1	1	1	7
{6}	1	1	1	1	1	1	1	7
{7}	1	1	1	1	1	1	1	7
{8}	1	0	1	1	1	1	1	6
{9}	1	1	1	0	1	1	1	6
{10}	1	1	1	1	1	1	0	6
{11}	1	1	0	1	1	1	1	6
{12}	1	1	1	1	1	1	0	6
{16}	1	0	1	1	1	1	1	6
{20}	1	1	1	0	1	1	0	5
{21}	1	1	0	1	1	0	1	5
{22}	1	1	1	1	0	1	0	5
<b>Total</b>	<b>12</b>	<b>10</b>	<b>10</b>	<b>10</b>	<b>11</b>	<b>11</b>	<b>8</b>	

From the primary articles, {5} {6} and {7} scored on all questions raised, these articles deal with models and cloud adoption in health/care environments, therefore, are aligned with the research objectives and realize that the survey, a priori, brought work that aggregated in the analyzes made. The qualitative and quantitative assessment analyzed all 39 studies selected as primary studies. Table 2 presents a portion of the studies and highlights the studies that had 5 or more points.

### III. DISCUSSION

After analyzing and extracting data in the primary studies, it was possible to identify some aspects related to cloud computing in health environments with economic impacts, opportunities, and challenges. According to Ferraz [3], it is possible to conclude that the adoption of cloud computing in the development of a new solution or business has a great impact on the economy of companies and industries. It is noteworthy that this article does not intend to study only the impacts related to healthcare. However, it was observed during the research, a large number of studies related to this theme and the possible implications on the use of cloud computing.

#### A. Economic Health.

Adopting cloud computing can bring health benefits, both economically and help institutions fight and prevent disease as quickly as possible. According to the study by Chang and Zhu [5], in modern and current hospitals, the use of cloud computing becomes more centralized data management, making hardware and software maintenance more convenient. Hospital environments that adopt physical servers need to invest large amounts in IT, staff responsible for the infrastructure, maintenance and security of the machines used. In addition, over time, the model becomes increasingly obsolete and costly. This is the fundamental change brought about by the cloud, the virtualization of resources without the need to maintain an expensive on-site infrastructure [3].

As seen in [6] biomedicine labs can enjoy positive financial impacts, significant flexibility and benefits to their administration by using a cloud architecture. This brings new solutions that can transform the hospital economy [7], and business models begin to emerge with a new vision in their solutions. Because all infrastructure can be abstracted by the cloud, those involved in creating solutions can be more focused on the problem to be solved, bringing innovative solutions that change the way the economy of these solutions works.

#### B. Cloud Treatments.

The benefits of cloud computing adoption go far beyond financial impacts and cost savings. Although the impact of cloud computing adoption has generated around the economic sphere, major advances in medicine can be seen in the use of this and other technologies together.

As can be seen here [8], the authors presents the Disease Diagnosis and Treatment Recommendation System

(DDTRS) which uses big data and cloud computing to generate diagnoses and treatment recommendations efficiently and assertively, improving the response time of diagnosis.

Another medical cloud use [9] promotes blood pressure monitoring in a patient with hypertension. Since monitoring is done in real-time, the number of data generated is huge and requires an IaaS structure framework for management.

The academic field also benefits from using cloud computing, whether in data storage, infrastructure or processing power. Complex studies at the forefront of medicine using the latest theoretical chemistry in the treatment of cancer [10] generate huge amounts of data and require enormous computational power for data processing. Research, such as [11] that simulates electron-nuclear dynamics of proton cancer therapy reactions, depending on the system studied, may take months to present the results. Therefore, cloud computing benefits by lowering its costs as infrastructure and the use of data science can generate great insights of the studied subject.

### C. Health Cloud Challenges.

Based on the previous Sections and the studies analyzed, three major sectors and specific areas were identified as cloud computing and health research challenges and opportunities. They are security and privacy, chronic disease and cloud, cancer treatment and prevention. In the first area, the need to ensure the security, privacy, and authenticity of the information was identified. Any information that may lead to the identification of the user by an unauthorized party during authentication or data processing is a breach of privacy [12]. Because most data is stored on cloud servers, which is susceptible to threats and breaches, there is an imminent need to protect against unauthorized access. There are many challenges to protecting the privacy of cloud patient data; some models have been proposed [13][14]. Even so, it is clear, including several studies, that this area is extremely important for the future of the use of cloud as a whole not only limited to health.

The second specific area is shown in the development of solutions for chronic diseases. The emergence of emerging technologies demonstrates opportunities and challenges [15]. Most of these technologies have in common the need to use cloud computing in their development. Therefore, further studies and innovative solutions can change the way we treat these diseases in a few years.

Finally, studies and solutions that advance cancer treatment and diagnosis deserve attention as they can generate major economic impacts on cancer treatment and

prevention. The American Cancer Society (ACS) estimates that 606,880 Americans will die of cancer by 2019, or nearly 1,700 deaths a day. This area generates a huge amount of data for storage and requires very large data processing power [11]. The search for cancer prevention combined with innovative solutions and cloud computing should be a priority area of study, considering the numbers presented by ASC. The development of SaaS or IaaS solutions is a great opportunity for the area.

## IV. CONCLUSION

The main objective of this work was to conduct research that analyzed areas related to cloud computing, specifically in the health environment, deepening how this technology impacts health and solutions for this market. To achieve the objective, a systematic mapping was performed, first analyzing 5280 articles and deeply analyzing more than 100 articles in order to discuss topics not only related to the technology itself, but how its adoption impacts the health area and the economy of its own solutions.

During the analysis phases, it was clear the benefit of adopting cloud computing and how the combination of technologies can bring disruptive solutions to the market and society. Biomedicine labs and research centers also benefit from adoption, reducing response times for exams or surveys that require extensive processing and storing data. As future work, further analysis of solutions can be developed, facilitating better technical understanding to identify more efficient approaches. Further work can be done to ensure data privacy and security, and how governments will ensure privacy in public health policies.

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